Of Matters Condensed

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Abstract

The American Physical Society (APS) March Meeting of condensed matter physics has grown to nearly 10,000 participants, comprises 23 individual APS groups, and even warrants its own hashtag (#apsmarch). Here we analyze the text and data from March Meeting abstracts of the past nine years and discuss trends in condensed matter physics over this time period. We find that in comparison to atomic, molecular, and optical physics, condensed matter changes rapidly, and that condensed matter appears to be moving increasingly toward subject matter that is traditionally in materials science and engineering.

Introduction

Condensed matter physics studies beautiful fundamental physics, such as superconductivity, while simultaneously providing important inventions including the transistor, CCD, integrated circuit and diode laser. Moreover, the field holds promise for future applications, such as dissipationless power transfer and quantum information processing. The American Physical Society (APS) March Meeting is arguably the largest condensed matter physics conference and attracts nearly 10,000 participants to a single location to discuss the topic. These participants include undergraduate students, graduate students, postdocs, staff scientists, professors, engineers, vendors of scientific instruments, and journalists both from around the world. Sessions include numerous contributed talks, posters, invited talks, (so-called "crackpot" sessions), and exhibits, and provides all physics enthusiasts an opportunity to deepen their knowledge of their respective fields of specialization, as well as to gain exposure to new, emerging fields in condensed matter. The March Meeting, therefore, offers a snapshot of progress in the represented fields, and is a good measure of the trends in condensed matter. We scraped the abstract content from the March Meeting programs from 2007-2015 to examine and analyze these trends, and speculate about the future of matters condensed.

Some simple numbers

We begin with the most basic of trends. The field of condensed matter, as measured by the number of contributed abstracts to the March Meeting has shown steady growth since 2007 (Figure 1**a**). This finding is somewhat surprising, given the sentiment that interest in condensed matter was inflated by the discoveries of the 50's, 60's and 70's, and has subsequently begun to wane. In fact, as measured by arxiv submissions, the growth of condensed matter has slowed, and its relative contribution to the entire arxiv pool has steadily dropped since approximately 2002[1]. The steady growth of abstracts in the presence of a decrease in arxiv submissions can be attributed either to submissions of historically "cond-mat" articles to other areas (such as "quant-phys"), or to an increase in unpublishable abstract submissions. However, our expertise is in only a small subset of March Meeting and condensed matter fields, and we therefore cannot adequately judge the publishability of results. Lastly, we note remarkable consistency in both the length (in words) and number

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[1] http://arxiv.org/help/stats/2014_by_area/index

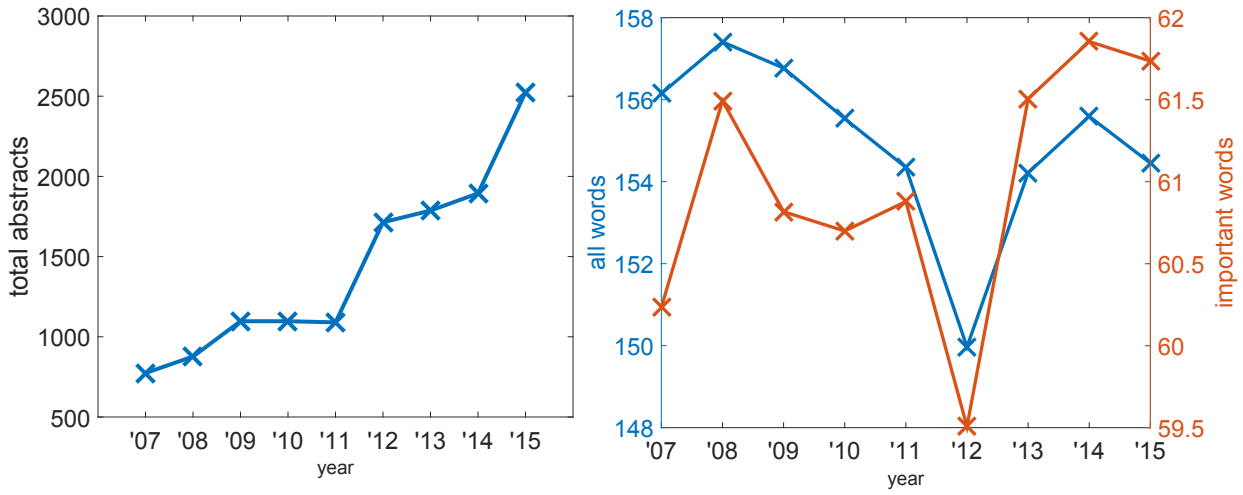

Figure 1: **a:** The number of abstracts submitted to March Meeting has steadily risen since 2007. **b:** The total words per abstract and important words per abstract have remained approximately constant.

of important keywords (as defined below) in each abstract (Figure 1**b**), suggesting that contributors have continued to obey the APS abstract guidelines, and tend to the same point in the tradeoff between readability and information density.

Single word analysis

We employ standard procedures used in natural language processing to analyze the text. We treat each abstract in the "bag of words" approximation, using only word frequency, and neglecting word order and context. Additionally, we "clean" text, stripping away suffixes to more accurately group together similar words, creating a dictionary of 24000 words. Lastly, we ignore common words, and normalize all word counts by the total number of abstracts in a given year. This creates a document matrix for each March Meeting from 2007 to 2015, containing the percentage of abstracts which contain a specific word.

We use these word counts to analyze various trends in March Meeting abstracts. For example, we can see the rise and fall of various families of high-temperature superconductor, though these trends are indeed dominated by an "envelope" of dimishing interest in superconductivity (Figure 2). We attribute the rise in abstracts which reference superconductivity to the recent interest in topological superconductivity and Majorana Fermions.

We gain further insight into the direction of condensed matter physics by eximining this decline in popularity of superconductivity, with the voltile behavior of graphene, and the steady trend toward studying interesting materials (Figure 3);

Big movers

We choose the salient words to examine by finding the words which are among the 1000 most popular keywords in all the years. We then compute the slope of line ($\frac{dP_{word}}{dt}$) for each of the feature words, where P_{word} is the fraction of abstract with a particular word, and we identify the "big movers" as the keywords with very large (positive or negative) slopes. In Figure 4 we plot the trends of some of the relevant big losers of the plast nine years, including superconductivity, which has likely seen a descreasing interest due to difficulties with high-temperature superconductivity. There are some more surprising terms with declining popularity over the past nine years, including "conden" and "science," though it is unclear why. We leave the reader to draw additional conclusions and to make further speculations based on these data.

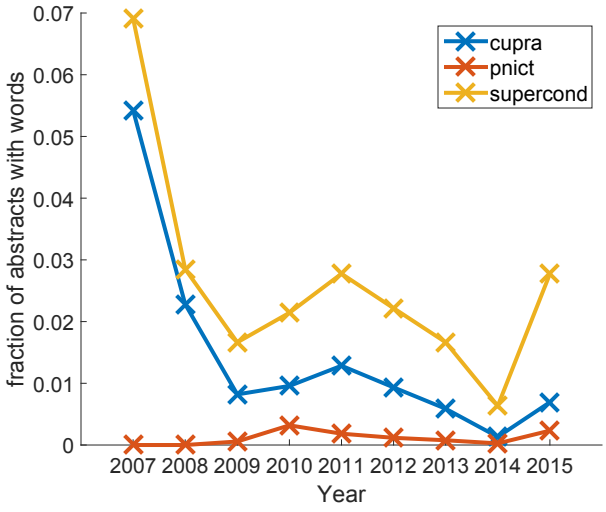

Figure 2: The trends in popularity of various kinds of high-temperature superconductors are largely dominated by the decline in popularity of superconductivity itself.

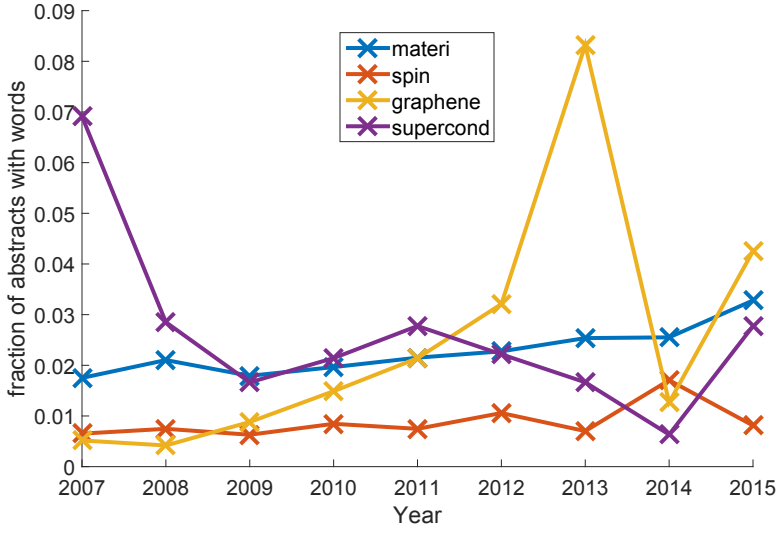

Figure 3: While superconductivity shows nearly steady decline, other topics such as materials show steady growth in popularity.

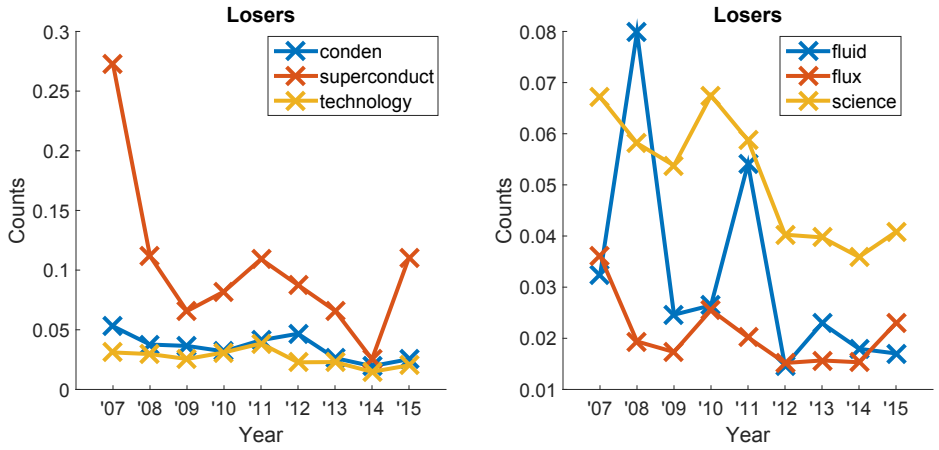

Figure 4: Some surprising (e.g. "science") and unsurprising (e.g. "superconduct") salient words with large losses in popularity over the last nine years.

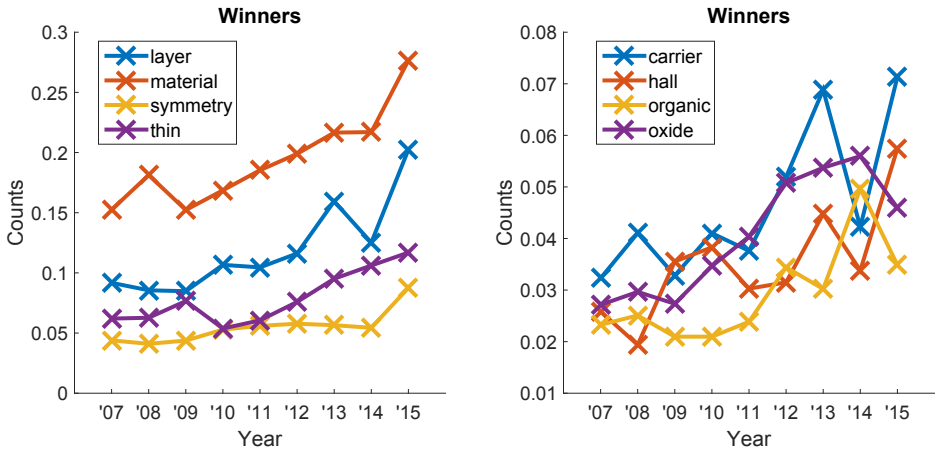

Figure 5: Some salient words with large gains in popularity. These are largely associated with material science, suggesting that the field of condensed matter is moving toward subject matter that is typically associated with material science.

We plot some of the terms with the largest increases in popularity over the past several years in Figure 5. The subject matter with large increases largely pertain to interesting materials and material properties, and these trends appear to continue, or perhaps strengthen, up to 2015.

Latent semantic analysis

We confirm these observed trends, as well as make more quantitative claims using latent semantic analysis. We create a sparse $N_{abstract} \times N_{words}$ matrix for each year containing word counts for each abstracts. Using singular value decomposition we reduce the dimentionality of these matricies and find the salient word-feature vectors. In 2007, for example, the words with the most weight in the feature vector with the largest singular value in descending order are:

```
{supercond, dop, gap, magne, wave, curpa, state, pair, low, meas,
 high, spin, delta, show, stat, CuO, tunnel, electro, phase}
```

which we recognize as representing "high-temperature superconductivity." Similarly, for 2014, we find the highest weight words in the feature with the largest singular value to be:

```
{magnet, spin, field, ferro, temperature, order, meas, coupl, aniso,
 antiferro, lattice, low, exchang, orbit, frustr, neutron, momentum}
```

which we identify as "novel magnetic materials" and for 2015 we find

```
{film, propert, sub, layer, thin, high, micro, materi, depo, appli,
 grow, spectrum, device, nano, meas, ray, surface, studi}
```

which we idenity as "novel layered materials." Indeed, our suspicions of trends in subject matter away from high-temperature superconductivity toward topics which border matieral science are confirmed.

For comparison, we can repeat the same analysis on abstracts from the division of atomic, molecular and optical physics (DAMOP), and we find much more uniformity among feature vectors from year to year. For example, the most significant words of the feature vector with the largest singular value for 2007 are

```
{optic, quantum, atom, phase, trap, field, condens, lattice, two,
 demon, magne, cool, frequenc, pair, ultra, light}
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and for 2014[2] are

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{optic, quantum, spin, lattice, ultra, trap, atom, condens, magne,
 progra, phase, many, body, dimen}
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There is significant overlap between these two vectors (the years between 2007 and 2014 are also similar), and both could be classified as "quantum optics with ultra-cold atoms."

Outlook and conclusion

Despite what the arxiv submissions might suggest, it appears that condensed matter is vibrant and growing, at least in the short term. However, it appears that it adapts to the pervading climate of the times, and the subject matter has evolved from "traditional" condensed matter physics such as superconductivity, to subject matter on the border with material science. As Figure 4 and the latent semantic analysis suggests, condensed matter may be less focused on the "condensed," but has branched out into the more applied field of materials science. We see no signs of this trend stopping (nor any reason to resist it) and we speculate that as funding and interest correlate with applications, that the field will continue to trend to the more applied.

Acknowledgements

The authors acknowledge John Nichol for fruitful discussions.

[2] the 2015 abstracts are not yet available